incumbent licensees, and for large antenna geostationary satellite operation. It is also the only pair with the requisite World Region 2 allocations necessary for both space and ground mobile services. As such, it must be reserved in its entirety for satellite use and, more specifically, for HPCS services.

3. *Other Changes From CELSAT's Original Initial Petition*

Initially, CELSAT anticipated that it would be sharing the RDSS L/S spectrum only with MSS systems. As such, CELSAT did not propose specific rules for *full HPCS sharing*. Now,, given the superior advantages of the HPCS approach vis-a-vis the pure MSS approach, CELSAT is urging that the Commission ought to favor HPCS licenses over stand-alone MSS systems in the requested allocation. Moreover, just as it was shown to be technically feasible to apply band interference sharing techniques to multiple MSS systems, CELSAT submits that band sharing works, within limits, for HPCS systems as well.[56] Therefore, consistent with CELSAT's commitment to this superior use of the spectrum, full band interference sharing is proposed, both in space and on the ground.

In an a good, clear band environment with no incumbent problems two or more HPCS systems can share the space component of the ET Space Band very successfully using full band interference sharing. If the sharing systems are each well designed, and if certain necessary EIRP and PFD sharing constraints are adhered to, all systems can operate reasonably close to their maximum design capacity were each system operating without sharing constraints. What is further important, however, is that the aggregate total capacity of all sharing systems will be <u>greater</u> than the capacity of any one system operating in the band alone.

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[56] To the extent there was any serious challenge by Motorola to the concept of full band interference sharing, that challenge was focused on either the economic viability or technical feasibility <u>of certain proposed MSS systems</u>, and not at the technical feasibility of the sharing method. CELSAT's CELSTAR system, incidentally, was <u>not</u> one of the systems criticized in that proceeding, but was the one system about which there didn't appear to be any doubt among the MSS Negotiated Rulemaking participants as to its capacity to share.

This fact ensures that the public will realize a net benefit from sharing. This is illustrated in charts from the MSS Majority Report, attached as Appendix B.[57]

CELSAT submits, however, that there are practical limits to such sharing, particularly in a heavily congested band, which, for the foreseeable future, ought to be reflected in the Commission's HPCS rules. These limits should include the following:

a. Full-band interference sharing should be mandated only as to the space component of the HPCS system; sharing at the ground-component level should be achieved first, through negotiation and voluntary coordination between the parties, and, only if that fails, by mini-band segmentation by default.

b. Sharing of the space component should be limited to two HPCS systems or, if a second HPCS applicant doesn't come forward, to one HPCS and one MSS licensee.[58]

c. Entry by the second sharing licensee should be delayed until an adequate amount of spectrum has been cleared of incumbents; entry at that time should be further conditioned on a commitment to reimburse the primary licensee for a *pro rata* share of the cost of clearing the band or any portion of it.

d. At such time as the second HPCS license is granted, and unless the sharing licensees agree otherwise, the amount of spectrum committed for terrestrial use shall not exceed 5 MHz in each band. If the HPCS licensees cannot negotiate some other joint use or coordinated allocation of the five MHz for terrestrial use, each licensee shall, by default, be allocated 2.5 MHz per band for its exclusive use, either in space or on the ground.

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[57] CELSAT submits that the MSS Majority Report does not do complete justice to the sharing potential of the full band interference sharing method. This is because, among other reasons: (1) the applicant systems were greatly mismatched relative to CELSAT's much greater system capacity; and (2) the other candidate systems were otherwise not optimally designed for sharing -- both factors thereby bringing down the apparent maximum achievable sharing benefit.

[58] As set out in the proposed rules at Appendix A, the first full service HPCS licenser would be the "primary" license and would be permitted to (i) use up to four subbands for ground purposes, (ii) select the ground subbands for ground use from anywhere within the full band spectrum, and (iii) such subband selections need not be uniform across the whole system. This flexibility will be [illegible]

CELSAT submits that the full HPCS concept is so powerful and so robust that it ought to be encouraged within the prime band to the maximum possible extent. Access to the *prime* 1970-1990 MHz and 2160-2180 MHz bands therefore, should be limited to full HPCS systems; only in the event a second HPCS system does not materialize should a compatible MSS-only systems be licensed in this band.

a. <u>Sharing of the Space Segment Only</u>

While CELSAT is proposing that the ET Space Band should be limited to HPCS licensees only, the limited available bandwidth and the difficulty of coordinating the terrestrial hub locations[59] and adaptive reassignment of ground and space subbands among multiple HPCS licensees virtually guarantees that sharing *terrestrial* spectrum in the same band will not work well, if at all. Therefore, CELSAT is proposing that the two HPCS licensees be permitted to operate no more than a combined total of 5 MHz (e.g., four 1.25-MHz CDMA subbands), to be selected from anywhere within the band on a space cell-by-space cell basis for terrestrial communications.[60] This spectrum could either be operated jointly per agreement or, failing agreement, each licensee would be permitted to use up to 2.5 MHz exclusively (i.e., on a non-shared, band segmented basis) for hybrid services. The rest of the band would be shared using CDMA full band interference sharing for space-based service.

b. <u>Limit of Two HPCS Space Component Sharers</u>

CELSAT was a strong advocate of the MSS Majority Report's conclusion that spread spectrum full band interference sharing is the preferred, optimum method for sharing satellite bands and for accommodating multiple entry. Indeed,

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59 Due to significant so-called near-far problems, it is not feasible to operate multiple terrestrial cellular systems on a full band sharing basis unless <u>all</u> system ground hubs are co-located.

60 The primary HPCS licensee would have to coordinate with the other sharers of the space component as to which subbands were being used terrestrially, and in what geographic areas.

as CELSAT so effectively propounded throughout the MSS Negotiated Rulemaking proceeding, such sharing is a better, more efficient sharing technique.

However, as the MSS Majority Report arguably also demonstrates, if too many or an unlimited number of parties are permitted to share a limited spectrum band, one or more such systems will likely cease to be economically viable, even if each is well designed. This suggests that some limit should be placed on the number of potential sharers up front and by rule especially where, as here, there are particularly severe constraints on the available band, Otherwise, in general no meritorious system should be exposed to failure unnecessarily -- that is, just for the sake of more multiple entry at the cost of significantly increased probability of failure.

The particular constraint on the ET Space Band not present in the MSS/RDSS band is the heavy congestion from incumbent users. The amount and position within the band of spectrum available for effective sharing will vary across the country by geographic region. This not only aggravates the sharing coordination problem, but it severely and understandably requires a much lower number of potential sharers than what is being considered feasible, for example, in the MSS/RDSS band.

Therefore, CELSAT believes that it would be reasonable to limit the number of HPCS licensees (or combination of HPCS and MSS-only licensees) in the ET Space Band by rule to two. All other things being equal, and under the default sharing criteria developed in the MSS Majority Report and slightly revised in Appendix B hereto, the capacity of each participant would be reduced to approximately 60% relative to its capacity operating alone.[61] But if the two systems were comparable in terms of their individual capacity alone, the *aggregate* capacity under sharing would be 180% of that of any one HPCS operating alone. Such a beneficial aggregate capacity would not be attainable in a band

c. Sharing Should be Delayed

CELSAT is confident of the fundamental validity of sharing the space segment of the band with another CDMA HPCS entity. However, in view of the added complexity and unprecedented problems of initial accommodation with the incumbent fixed services, and the prospect for voluntary coordinating negotiations for relocation of many of these incumbents, CELSAT urges that initially there should be only a single licensed entity until such time as the clearing process has achieved a substantial definable level of incumbent clearances and fully compatible operations have been demonstrated with the remainder.

In support of subsequent sharing, the rules should further provide for mandatory negotiated compensation by a subsequent licensee to the primary licensee for its expense and risk incurred in prior band clearing.

CONCLUSION

Accordingly, the commission should amend its rules as proposed herein and as set forth in Appendix A attached hereto.

Respectfully submitted,
CELSAT, INC.

By: ______________________
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July 7, 1993

CERTIFICATE OF SERVICE

This is to certify that a copy of the foregoing Amendment to Petition for Rulemaking has been served this date by U.S. Mail to counsel for the parties herein, addressed as indicated on the attached list.

____
Victor J. Toth

July 7, 1993

APPENDIX A

APPENDIX A

Allocation and Technical Rules for Hybrid Personal Communications Service

The following rules are being proposed by CELSAT for a new satellite-based Hybrid Personal Communications Service (HPCS) consisting of both space- and ground components in either the same contiguous band or in non-contiguous bands. However, for this specific allocation request both the space and ground components of the HPCS service will be in the same bands and shall be shared either among two HPCS licensees on a primary basis, or between one HPCS and one MSS-only licensees.

Many of these proposed rules pertaining to CDMA sharing coordination were drafted and adopted by the Majority Report of the MSS Advisory Committee and were subscribed to by CELSAT. Insofar as an HPCS allocation as proposed herein contemplates potential *intraservice* sharing of a satellite component between either multiple HPCS systems or between an HPCS system and a conventional MSS systems operating in the same bands, CELSAT submits that rules such as these are necessary to the expeditious development of the HPCS service, and urges that they be adopted.

PART 2 of Chapter I of Title 47 of the Code of Federal Regulations should be amended as follows:

<u>Amend</u> Section 2.106, the Table of Frequency Assignments, as follows:

a. In column (5) at the 1850-1990 MHz band: change 1850-1990 MHz to 1850-1970 MHz, and add "1970-1990 MHz, HPCS (Earth-to-Space);

b. In column (6), opposite the new entry at 1970-1990 MHz, add "Hybrid Personal Communications Service (21, 22 and 25);

c. In column (5) at the 2160-2200 MHz band, change 2160-2200 MHz to 2180-2200 MHz, and add "2160-2180 MHz, HPCS (space-to-earth); and

d. In column (6)opposite the new 2160-2180 MHz, add "Hybrid Personal Communications Service (21, 22, and 25).

Part 25 of Chapter I of Title 47 of the Code of Federal regulations should be amended as follows:

<u>Amend</u> Sec. 25.103, Definitions, to include the new definition (i) for Hybrid Personal Communications Service:

(i) *Hybrid Personal Communications Service.*

1. The term *Hybrid Personal Communications Service* refers to an integrated complex of space and ground based facilities providing:

a. Satellite personal/mobile communications and position determination services over the United States;

b. Ground cellular and/or microcellular personal/mobile and position determination services within space cells;

c. User transparent, integrated management of assignement and transfer of functions between space, ground and microcellular components;

d. User service options including but not limited to voice, paging, facsimile, variable speed data, and compressed video.

2. The scope of permissible offerings in the HPCS service allocation is to be broad and shall include, but is not limited to, any digital one-way or two-way communications of voice, data, video, audio, image or position determination information originated or terminated over a hybrid personal communications system or network to or from either a portable, mobile or special purpose fixed terminal or receiver operated at low power with unswitched low gain antenna for either point-to-point or point-to-multipoint personal, business, commercial or public safety purposes over land, air and water.

<u>Amend</u> Subpart B by adding new Section 25.121 Special Licensing Considerations In the *Hybrid Personal Communications Services*.

§25.121 **Special Licensing Considerations In the *Hybrid Personal Communications Services*.**

(a) **Primary and Secondary HPCS Licensees.** (i) The first HPCS applicant to be granted a licensee shall be designated the *primary* licensee; the second HPCS and/or MSS-only licensee shall be *a secondary* licensee. (ii) The primary licensee shall be permitted to commence full HPCS operation anywhere within the spectrum band on an exclusive, non-shared basis and without limitations until such time as a reasonable amount of the allocated spectrum has been cleared of incumbent users across at least 80% of the United States. A secondary licensee will be permitted to commence operations once such cleared condition has been attained, subject to a condition that it enter into an acceptable and reasonable compensation arrangement with the primary licensee for the costs of previous and continuing clearence efforts, or until such time as a mutual band clearing arrangement can be agreed upon. (iii) Primary and secondary licensees shall agree on coordination of up to 1.25 MHz of common HPCS spectrum in the 1970-1990 MHz (earth-to-space) band for control purposes. (iv) Once a secondary licensee commences operation the amount of the allocation being used at any point in time for terrestrial communications shall not exceed 5 MHz in each band unless otherwise agreed to by the sharing licensees In no event shall the amount used for terrestrial purposes exceed 50% of the full allocation.

(b) **Band sharing** -- Space Component. (i) The space component of an HPCS allocation consisting of not less than 13.75 MHz in the 1970-1990 MHz band and 15 MHz in the 2160-2180 MHz band of the initial HPCS allocation may be shared by either two HPCS licensees, or by one HPCS licensee and one MSS-only licensee. (ii) Band sharing of the space component

Amend Section 25.114(c) with the following new subsection:

(27) Applications for MSS space-component authorizations in the Hybrid Personal Communications Services in the 1970-1990 MHz and 2160-2180 MHz bands shall also provide all information specified in Sec. 25.141.

Modify Section 25.141 of the Commission's Rules to read as follows:

Sec. 25.141. Licensing Provisions For The Hybrid Personal Communications Services in the 1970-1990 MHz and 2160-2180 MHz Bands.

(a) Space station application requirements. Each application for a space station license in the Hybrid Personal Communications Services in the 1970-1990 MHz and/or 2160-2180 MHz bands shall describe in detail the proposed Hybrid Personal Communications Service satellite and ground system, setting forth all pertinent technical and operational aspects of the system, including its capability for providing hybrid personal communications service on a geographic basis, and the technical, legal and financial qualifications of the applicant. In particular, each applicant shall include the information specified in Section 25.114, except that applicants for non-geostationary MSS components of Hybrid Personal Communications Service systems, in lieu of providing the information concerning orbital locations requested in Section 25.114 (c) (6), shall specify the number of space stations that will comprise its system and their orbital configuration, including the number of planes and their inclinations, altitude(s), argument(s) of perigee, service arc(s), and right ascension of ascending node(s). Applicants must also file information demonstrating compliance with all requirements of this section, specifically including information demonstrating that they will not cause harmful interference to any authorized or licensed Mobile Satellite and Hybrid Personal Communications Service system.

(b) User transceivers. Individual user transceivers will not be licensed. Service vendors may file blanket applications for transceiver units using FCC Form 493 and specifying the number of units to be covered by the blanket license. FCC Form 430 should be submitted if not already on file in conjunction with other facilities licensed under this subpart. Each application must show that its user transceiver units will comply with the technical parameters of the satellite system(s) with which the units will communicate.

(c) Permissible communications. Stations in these bands shall not be limited in the provision of personal and mobile and radiodetermination satellite communications services, and shall be permitted to provide such services in the air and over land and water.

(d) Frequency assignment policies. Each satellite system authorized under this section will be assigned the entire allocated frequency bands on a non-exclusive basis. Coordination procedures and power limits as set forth in subsections (e) and (f) below shall be employed to avoid harmful interference with other satellite systems in these bands.

(e) Mobile Satellite and Hybrid Personal Communications Services satellite system coordination procedures.

(1) Licensees shall coordinate with other licensees to avoid harmful interference to Mobile Satellite and Hybrid Personal Communications Services satellite systems in these bands. During the coordination processes, licensees shall exchange relevant information and interference calculations, subject to appropriate confidentiality arrangements, and shall meet as necessary to negotiate in good faith to resolve potential interference problems. Coordination hereunder shall be a continuous process, taking into account changes in system parameters, traffic configuration, and other relevant factors. Existing HPCS/MSS licensees shall coordinate with new HPCS/MSS licensees as authorized by the Commission, and in the absence of agreement, the Default Values specified as follows [See, Appendix B to this Amended Petition] shall apply.

(2) Technical coordination in these bands is based on the equitable allocation of interference noise among systems sharing these bands.

(3) Coordination agreements would typically be based on mutually agreed values of the following parameters of each system operating in the band:

(i) The maximum value of the downlink PFD at any point in the service area per system, averaged over an appropriate period of time. Polarization effects shall be considered when calculating the maximum PFD;

(ii) The maximum aggregate EIRP density simultaneously radiated by all user terminals for a single system within a defined aggregating area of the order of a minimal space cell size anywhere within the Continental United States averaged over an appropriate period of time;

(iii) Polarization;

(iv) Frequency plans;

(v) Code structures and associated cross correlation properties;

(vi) Antenna beam patterns; and

(vii) Signal burst structures.

(4) In the absence of mutual agreement during the coordination process referenced above, the operations of HPCS/MSS satellite systems licensed under this section will be limited to the default values of maximum downlink PFD spectral density and maximum EIRP areal spectral density established by the Commission and set forth [see, Appendix B to this Amended Petition], recognizing that such values may be subsequently modified by Commission order.

<u>Amend</u> Section 25.202(f) by inserting the following in the introductory paragraph:

(f) Emission limitations. Except as specified in subsections (g) and (h), the mean power of emissions shall be attenuated below the mean output power of the transmitter in accordance with the following schedule:

<u>Amend</u> Section 25.202 by adding the following new subsection:

(g) Emission limitations in the 1970-1990 MHz band, Earth stations. The mean power of emissions shall be attenuated below an amount equal to the mean output power of the transmitter times the fraction, 4 kHz divided by the authorized bandwidth, in accordance with the following schedule:

(1) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent (but at least 2.0 kHz) up to and including 150 percent of the authorized bandwidth: 26dB;

(2) In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 150 percent up to and including 250 percent of the authorized bandwidth: 38 dB;

(3) [illegible]

frequency by more than 300 percent of the authorized bandwidth: 43 dB;

(4) In any event, when an emission outside of the authorized bandwidth causes harmful interference, the Commission may, at its discretion, require greater attenuation than specified in paragraphs (h)(1), (2), and (3) of this section.

(5) For the purposes of paragraph (h) the authorized bandwidth is the larger of the occupied bandwidth (the 99 percent power bandwidth) or the necessary bandwidth of the transmitted signal.

(6) Upon a showing that the operation of the station will not cause harmful interference to other systems or services or that the out-of-band PFD is below coordination and interference values, the limits of Sections (g)(1), (2) and (3) of this Section shall not apply.

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APPENDIX B

APPENDIX B
DEFAULT SHARING CONTROL VALUES

Uplink and Downlink power control values (limits) are essential to endure equitable full band sharing among diverse HPCS or MSS systems. They serve a function in the mobile satellite service entirely analogous to that of EIRP

APPENDIX C

APPENDIX C

SYSTEM CAPACITY AND SPECTRAL EFFICIENCY COMPARISON

The MSS Advisory Committee Negotiated Rulemaking Proceedings (MSSAC) provided an occasion to compare the capacity and spectral utilization efficiency of all current big LEO and GEO MSS proposers under comparable terms, and under the strict review of the entire community. The Comparative results are summarized in Table C-1 here from the Majority Report.[1] This summarizes the capacity determining design parameters for the various systems as modified (except for CELSAT[2]) during the MSSAC proceedings, and the resulting capacity as calculated by the committee. These results show CELSAT with a "Maximum Realizable Capacity" (the bottom line) approximately 4 times at 62,000 + CONUS circuits. This is almost identical to CELSAT's capacity statement for this case.

However, CELSAT believes that all the other parties have seriously understated or miscalculated one essential parameter in this calculation, the "Average Beam Overlap factor, (BOF) with values of 1.0 to 1.25 dB, as compared to 3.8 dB for CELSAT, resulting in an exaggerated statement of their Maximum Realizable Capacities by a factor of about 2 or 3 to 1.

BOF is defined as the ratio in dB, of the average power over all users, of the self-interference from other users of the system in the same plus all other beams to that from users in the same beam only. This calculation involves an integration of the co-frequency spillover power from all other beams and for useful accuracy, we find, must be carried out to least three to five beam radii out from the effected beam, in all directions. CELSAT is confident that its calculated value of this parameter is correct for its beam shapes. Furthermore, for fundamental reasons, any multi-beam system, having beam sizes about as small as can be supported by the system antenna aperture (i.e. diffraction limited), will necessarily have about the same beam shapes, and therefor very nearly the same beam overlap factor -- *unless* the system avoids interference from adjacent beams by using a cluster size greater than 1. A possible partial explanation of the anomaly is that several of the systems did indeed have cluster sizes greater than 1 prior to the redesigns that occurred in and as a result of these proceedings (See I.D.5 supra.), and the beam overlap factors presented in this chart may reflect an uncorrected hangover from prior designs using higher cluster numbers.

If this presumption is correct, then the relative capacity and spectral efficiency are more accurately reflected by the "Maximum Idealized Capacity" ratios (next to bottom line), in which CELSAT affords a capacity and spectral efficiency about ten times that of the nearest competing system design. This conclusion is further reinforced by the comparison of designers claims prior to these proceedings.

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[1] Final Report of the Majority of the Active Participants of IWG-1 to Above 1 GHz Negotiated Rulemaking Committee, April 6, 1993, Table on p.5-5.

[2] See, Id., Section I.D.5.

.1 Individual System Capacities

Using the equations given in section 5.1.2.2 above, the maximum ideal downlink acity, C_{MID}, and the maximum realizable downlink capacity, C_{MRD}, for the CDMA icants' (and Celsat's) systems have been calculated, using current input data ided by the proponents of the systems. This analysis does not take account of the of orthogonal CDMA, and assumes that all received PFD acts as interference. The data and results are given in Table 1 below.

n Parameter	Units	AMSC	Constell'n	Ellipsat	Globalstar	Odyssey	Celsat
nd Bit-Rate	(kBPS)	3.0	4.8	4.8	4.8	4.8	5.0
l Activity Factor	(#)	0.40	0.50	0.40	0.50	0.40	0.35
F Bandwidth	(MHz)	16.5	16.5	16.5	16.25	16.5	16.5
n Operating Eb/No	(dB)	4.0	3.0	3.0	3.5	3.5	4.0
r of Beams in CONUS	(#)	6	10	10	20	16	149
requency Re-Use Factor	(#)	1	1	1	1	1	1
Propagation Margin	(dB)	2.00	2.20	2.60	2.00	2.03	2.00
Orbit & Beam Effects	(dB)	2.50	3.50	2.50	2.11	2.00	1.70
Power Control Impl. Mar.	(dB)	1.50	2.00	1.00	1.00	1.00	2.00
Beam Overlap Factor	(dB)	1.09	1.00	1.00	1.04	1.25	3.80
Aperture of Mobile Ant.	(dBm2)	-21.0	-29.0	-29.0	-29.0	-29.0	-29.0
emp. Mobile System	(K)	325	290	290	290	290	290
um Ideal Downlink CONUS y Limit (see Note 1)	(# of ccts)	32,844	34,457	43,871	[illegible]	61,418	[illegible]
um Realizable Downlink Capacity Limit (see Note 1)	(# of ccts)	6,418	4,846	8,306	14,678	14,464	62,763

<u>Table 1 (downlink)</u>

Note 1: It is not intended to operate the systems at these maximum realizable downlink capacity limits. Satellite power level constraints will dictate the individual system power levels and corresponding capacities.

Note 2: Motorola believes that certain values for some of the parameters in Table 1 need to be adjusted to reflect what it considers should be used to operate in real world conditions, and therefore cannot agree with the capacity numbers calculated in the table. See Note below.

Using equation (5) from section 5.1.2.2 above, the realizable downlink capacity of the systems, when operating both in isolation and in the presence of other interfering systems, has been calculated, and the results are given in Figures 1 to 6 below. Four curves are given for each system, as follows:

a) "No interferer": Assumes that the wanted system only experiences self-interference (i.e., no orthogonal CDMA advantage assumed).

b) "Interferer = Noise - 3 dB": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is 3 dB below the thermal noise level (ρ_{nd} - 3dB).

c) "Interferer = Noise": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is equal to the thermal noise level (ρ_{nd}).

d) "Interferer = Noise + 3 dB": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is 3 dB above the thermal noise level (ρ_{nd} + 3dB).

NOTE: Motorola's analysis is reflected in the work of Dr. Peter Monsen dated March 24, 1993. It is assumed that Motorola will include this document in its minority report.

APPENDIX D

APPENDIX D
SYSTEM INVARIANT MSS UPLINK AND DOWNLINK SHARING CRITERIA

[The following paper, substantially as submitted by CELSAT to MSSAC as

times in these proceedings that the power efficiency (circuits per watt) and the spectral efficiency (circuits per MHz) of an MSS band sharing system, depend on the ratio, r, of total (including self-) interference spectral density to fundamental receiver noise spectral density. When that ratio is very small the bandwidth spectral efficiency is poor; when the ratio is large, power efficiency suffers as and G the satellite antenna gain.

The total effective isotropic interference power spectral density, β, radiated from within the footprint is then

$$\beta = \epsilon A_f$$
$$= 4\pi R^2 \epsilon / G.$$

Finally, the available interference power spectral density at the satellite receiver front end, I_s is just this total radiated power, times the transmission loss including free space loss and antenna gain,

$$I_s = \beta G \lambda^2 / (4\pi R)^2$$

or:

$$\boxed{I_s = \epsilon \lambda^2 / 4\pi}$$

Thus the factor $G/4\pi R^2$ cancels out and *the interference level at the receiver input is exactly independent of G and R.*

Equating the interference to thermal radiation at temperature, T_e,

$$kT_e = \epsilon \lambda^2 / 4\pi.$$

This equation is familiar to radio astronomers as the Rayleigh-Jeans law for radiation from uniform extended radio noise sources. This is a remarkable and perhaps counter-intuitive result:

> *The interference spectral density at an MSS satellite receiver front end, from a uniformly distributed source over the beamwidth of the satellite antenna, depends only on the effective isotropic radiated power areal-spectral density of the source and the wavelength of the radiation, and is independent of satellite antenna gain and altitude or distance from source to receiver. Similarly, the noise spectral density depends only on the effective noise temperature of the earth in the field of view of the antenna.*

Thus, such a criterion ensures that all just complying systems operate at the same interference-to-noise ratio and at the same potential power and spectral efficiency, that is it treats all systems equitably, irrespective of altitude, whether LEO or GEO and irrespective of satellite antenna gain.

For a given frequency band, the satellite receiver front end interference spectral density, I_s, depends *only* on the EIRP areal-spectral density, ϵ, (W/m^2/Hz) on the surface of the earth. At 1610 MHz for example, the relation is simply

$$I_s = 0.00276\ \epsilon \qquad \text{(W/Hz)}$$

It is useful as a point of reference to define a uniform source interference density or brightness, ϵ_{290} that causes an interference level at an MSS satellite receiver input equal to the antenna noise due to the assumed 290 K earth radiation. In other words,

$$0.00276\ \epsilon_{290} = 290\ k$$

or:

(using k= 1.380E-23 W/Hz/K)

$$\epsilon_{290} = -178.4\ \text{dBW/m}^2\text{/Hz}\ ,$$

again independent of satellite characteristics.

The significance of the interference is thus completely characterized for any MSS satellite at any altitude by the ratio $\epsilon\ /\ \epsilon_{290}$, independent of satellite altitude or gain.

Practical Uplink Sharing Criteria

Table 1 gives calculations of system area aggregate EIRP density for the various current CDMA system designs, based upon the quantities in the first four columns:

Single user average EIRP
Spread bandwidth per user, i.e. per one segment.
Number of segments.
Claimed number of US users at orbital epoch peak.

The deduced brightness is given in the last two columns in fundamental and practical units. It will be noted that the various designs show a consensus concentration at about -162 to -166 dBW/m²/Hz. This is twelve to sixteen dB higher than the reference thermal value, -178.2 derived above. The reason is believed to be two-fold:

1. Allowance of an effective earth noise temperature well above 290 deg to provide for other in-band man-made interference sources, and

2. power has not been as critical a concern on the uplinks as on the down, so that designers have set the uplink operating point at a fairly high point on the S-curve, at the expense of power efficiency, in order to provide very high operating margins as compared to the down-link.

It would not be appear wise to flaunt this design consensus. Accordingly, as a default value, subject to renegotiation by the parties at interest, we propose a limit of -162 dBW/m^2/Hz.

An EIRP areal-spectral density limit is thus a *sufficient* condition for satisfactory sharing. It is not a *necessary* condition however. It is not necessary that the EIRP density be absolutely uniform as assumed in the derivation. An EIRP surplus in one part of a cell or beam can be traded off against a deficit in another part, without harm to another MSS band-sharing system, provided that the trade takes place *within a cell or beam footprint* of the potential victim. So long as this is the case, any MSS sharer can count on a predictable maximum aggregate EIRP within any of his beams.

Thus, in order that all providers can be protected and still provide maximum flexibility for geographical load shifting it is sufficient to impose a maximum aggregate EIRP defined on an area, A_a, equal to or somewhat smaller than the smallest system beam footprint. In view of current, proposed, and near term potential system designs it is suggested that the specified aggregating area, A, should be no larger than about 100 x 100 statute miles (mi).

There is another important reason that may call for an even smaller aggregating area. MSS is viewed ideally as a complement and not a competitor to terrestrial cellular systems. But if aggregating areas are set too large, there could develop a tendency to pile on subscribers in more lucrative metropolitan areas in competition rather than complementation to the ground cellular service. In the long run such a development would be to the detriment of the ability to support a ubiquitous coverage MSS service.

Based upon these considerations, and the value of -162 dB in fundamental units as derived above, we propose a default uplink Aggregate EIRP Density sharing criterion about:

$$AEIRPD_{max} = -162 \text{ dBW/m}^2\text{/Hz}$$
$$= -21.7 \text{ dBW/4kHz} \quad \text{in } 10^4 \text{ mi}^2$$

The uplink sharing criterion must also take account of the fact that, under largely autonomous power control by the subscriber units, the hub station does not have short term control of the power level nor voice activity, so that, from the point of view of the hub, the instantaneous aggregate uplink EIRP must be regarded as an exogenous random variable, the peak value of which could easily be as much as 20 to 30 dB above average but with almost vanishing probability. Accordingly, we would propose that such limit be imposed with an exceedance probability less than one in 10^3 when measured with an averaging time of 100 milliseconds. It is not implied

2. For Uplinks: Aggregate EIRP spectral density, less than -21.7 dBW/Hz per system, summed over 10,000 sq mi,

the principle power allocation regulations that will be essential for full band sharing are stated in a manner that is equitable to all sharers, indifferent to satellite altitude and antenna gain. The values given are near fundamental limits such as kTo, but slightly modified therefrom by design consensus of the values

APPENDIX E

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CELSAT/FIXED SERVICE INTERFERENCE ESTIMATES

[MATERIAL IN THIS APPENDIX HAS BEEN FILED UNDER CLAIM OF AND A REQUEST FOR CONFIDENTIALITY PURSUANT TO 0.459 OF THE COMMISSION'S RULES.]